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Research Article

THE METHODS OF PARTICLE MIGRATION ON EARTH AND IN SPACE

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ABSTRACT

Particles of dust or fluids exist both on earth and in space. Indeed, in astronomy, the interstellar medium (or ISM) is the matter that, in a galaxy, occupies the space between the stars and merges into the surrounding intergalactic medium. It is a mixture of gases, cosmic rays and dust. The gas can be in different forms such as ionized, atomic and molecular. For example, hydrogen and helium exist in interstellar gas. Solid particles, called interstellar grains, constitute interstellar dust. Do the methods of migration or transport of these particles differ in the two environments, terrestrial and spatial? The first medium is dense and has a strong attraction of gravity. The second is less dense and the particles float. How do these characteristics influence the movements of particles in gaseous fluids?.

Keywords: EDP, convection, diffusion, earth, ISM, wave equation, diffusion-convection equation.

INTRODUCTION

In the article [8], the author presented three known methods of particle migration in fluids: diffusion, convection and dispersion. Each phenomenon can be superimposed on others such as a thermal or magnetic or vibratory or mechanical phenomenon. We then speak of thermal diffusion or vibrational thermo solutional convection or even kinematic dispersion. The migration mechanisms can be natural or forced. They are natural when triggered by a natural imbalance. On the other hand, when they are realized following a provoked external force, they are called forced mechanisms. In this article, we will carry out a comparative study of these migration mechanisms in two environments: terrestrial and spatial.

Let's start first, by noticing that on Earth, there are two types of fluids: liquids and gases. On the other hand, in space, there is only one gaseous form. On Earth, nature is made up of matter and energy, see article [8]. Each material has its own properties. Thus, they are not all transferred by these 3 modes, presented previously, simultaneously. For example, minerals move in groundwater tables by three meth-ods: diffusion, convection and dispersion, see [3]. On the other hand, each energy has its own mode of transfer. For example, there are three modes of transfer of thermal energy (heat): convection, diffusion and radiation. Electromagnetic energy has other modes of transfer, for example induction or radiation. The studies on the migration of particles by terrestrial fluids have been studied for a long time by the scientific community, but what about the fluid-interstellar grains interraction? The same question can be asked regarding interstellar wave-grain interactions? In this work, interstellar waves include both cosmic rays and electromagnetic waves. However, generally speaking, cosmic waves like solar rays have cor-puscular and wave-like characteristics. They thus form a separate category different from those of energy waves, such as electromagnetic energy.

MODELING

There are many migration mechanisms in nature, we are interested in convection and diffusion. The **convection** is a transport phenomenon whichconsists in the entrainment of the elements by a fluid in motion. **diffusion** is an irreversible transport phenomenon thatresults in the migration of chemical or energetic species in a medium under the effect of molecular agitation. Therefore, convection is a macroscopic phenomenon, on the other hand, diffusion is a microscopic phenomenon.

Thesetwophenomena of particle transport in gaseous and liquid fluids are mathematically modeled by partial differentialfunctionaloperators. If the phenomenonisnatural, the system issaid to be conservative and the transport equationishomogeneous.

$$P.\phi = 0 \quad (1)$$

Otherwise, the transport phenomena are forced by the existence of an inhibitory or catlysous source, then a second functionalmember isadded to the transport equation.

$$P.\phi = f \quad (2)$$

the second memberis a function f

Convection and advection

In the scientific literature, advection and convection both represent a phenomenon of particle transport by the movement of a fluid. However, convection often applies to the movement of a fluid, due to the density gradients created by the thermal gradients. On the other hand, advection is the movement of a material due to the velocity of the fluid.

Example 1 ***Equation of transport by advection:****Convective thermal equation: When the movementof the fluid tends to homogenize the temperature Tin a conservative system, the mathematical model, called continuity equation, is*

$$\frac{\partial T}{\partial t} + \mathbf{u} \cdot \nabla T = 0 \quad (3)$$

When there is a source of heat or cooling causing the temperature to vary T, a second functional member is added to the model, as

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explained above. For example, the equation 7, models the phenomenon of air heating by heating or cooling by air conditioner in a closed room. For more details, see the book [5]

Example 2 ***Convective transport equation:*** *Assuming that the flow is governed solely by the convection in the mobile fluid fraction of the fluid, thetransport equation is written:*

$$\frac{\partial C}{\partial t}+\boldsymbol{u}\cdot\nabla C = 0 \quad (4)$$

In this equality, C is the concentration of the studiedparticle and u represents the velocity of the fluis. For example, in a porous medium saturated withwater, u is the Darcy velocity. C can be the concentration of a particle such as salt, limestone or a radioactive element. For more details, see the book[3]

Conclusion 3 *Despite the difference between thephysical definitions of convection and advection,mathematically, the modeling equations 3 and* **4***are similar. It is the same operator. In Cartesian coordinates, These phenomena are modeled by theoperator*

$$\boldsymbol{u}\cdot\nabla = u_x\frac{\partial}{\partial x}+ u_y\frac{\partial}{\partial y}+ u_z\frac{\partial}{\partial z} \quad (5)$$

where ∇*is the gradient operator and*$\boldsymbol{u} = (u_x, u_y, u_z)$*is the velocity field of the fluid.Sometimes, the study of the evolution of matterover time is necessary and an infinitisimal temporalgradient is added to the operator 5.*

$$\frac{\partial}{\partial t}+ \boldsymbol{u}\cdot\nabla = u_x\frac{\partial}{\partial x}+ u_y\frac{\partial}{\partial y}+ u_z\frac{\partial}{\partial z} (6)$$

The operators 5 and 6 apply both for scalar fieldsψ *and for vector fields* $\vec{V}$ *. Once the mathematicaloperator has been fixed, it suffices to finalize themodeling by fixing a second member; depending on whether the system is conservative or not.The velocity of the fluid* $\vec{u}$ *distributes an energy,like thermal transfer, or the concentration of a particle, like salt; inside it in the same way.Therefore, no matter the source of the fluid movement, whether it is a scalar field or a density difference or a temperature difference, the transportequation is the same. This also leads, that a forcedor natural convection, are modeled by the sameequation. However, when it comes to studying aparticular phenomenon, it is important to take intoaccount all the data involved in the transport ofparticles by a fluid. Thus, in some works, a system of equations is added containing for examplethe heat equation or mass variation equation. Another example is the convection phenomenon triggered by an external phenomenon, such as a vibratory movement. These movements are modeled by the Navier-Stokes equation*

Diffusion

Diffusion is a phenomenon by which a propagation medium, fluid or not, homogenizes the distribution of its mass components (particles) or energy (thermal or magnetic). The transport takes place in many directions, continuously, until reaching a homogeneous state, called the equilibrium state. In this paragraph, we will introduce the flow expressions. The diffusion transport equation is, in most cases, a divergence of the flow. However, in some fields of physics, flux is also a flow rate, related to a displacement of matter or a transfer of energy, this is not always the case because in physics, a flux is a surface integral of the normal component of a vector field on a given surface. The associated vector field is often called flux density. This definition joins that of the flow in mathematics.

Example 4 The diffusion of matter, designates the natural tendency of a system to homogenize the concentrations of chemical species in its interior. It is illustrated by Fick's law, which relates mass flux to the concentration gradient via the mass diffusion coefficient :

$$J_C = -D\nabla C \quad (7)$$

where D describes the mass diffusion matrix.

Example 5 Thermal diffusion or thermal conduction is a mode of thermal transfer caused by a temperature difference between two regions of the same medium, or between two media in contact. This phenomenon tends to homogenize the temperature in the same medium. Fourier's law describes the relationship between the thermal gradient (cause) to the thermal flux (effect) by the expression :

$$J_T = -D_T\nabla T \quad (8)$$

D_T being the thermal diffusion matrix.

Example 6 Thermo diffusion, as mentioned above, is a crossover phenomenon. It was born from the interaction of a flow of heat by conduction and a flow of matter by mass diffusion. The generated flow is mathematically modeled by the addition of new terms to the phenomenological laws describing the basic effects. Thus, the mass flux generated by the concentration gradient and the temperature gradient, is expressed by a summation :

$$J = -D\nabla C - D_T C_0 (1 - C_0)\nabla T \quad (9)$$

with $C_0$the initial concentration of the heaviest component. the term -$D\nabla C$comes from Fick's law, while the term $-D_T C_0(1 - C_0)\nabla T$describes the Soret effect.

Generally, the transport equation is the divergence of the flow with a second zero member, if the flow system is conservative :

$$div(-D\nabla T) = 0 \quad (10)$$

otherwise, if there is a source or an absorber of matter or energy, external to the flow system, the second member is taken into consideration in the equality 10 :

$$div(-D\nabla T) = f \quad (11)$$

Moreover, if the system is homogeneous is that the diffusion continues in the same way in all directions, then, the diffusion matrix D is the identity. The equation 11, becomes :

$$\Delta T = 0 \quad (12)$$

A solution of this equation appears in the book [4].

In vector energy physics, diffusion is a phenomenon by which a propagation medium producesa continuous distribution, in many directions, of theenergy of a wave.

Example 7 *The electromagnetic fields*$(\vec{E},\vec{B})$*verify Maxwell's equations, described in the article[11]. The magnetic flux or magnetic induction flux,often denoted* Φ*, is a measurable physical quantitycharacterizing the intensity and spatial distributionof the magnetic field. This quantity is equal to theflux of the magnetic field* $\vec{B}$ *through an oriented surface* $\vec{S}$*. This flow is by definition the dot product ofthesevectors, see equation 13. Its unit of expression in the InternationalSystem of Units is theweber.*

$$\begin{aligned} d\Phi &= \vec{B}\cdot d\vec{S} \\ &= \|\vec{B}\|\cdot\|d\vec{S}\|\cdot\cos\theta \end{aligned} \quad (13)$$

Hence, the flow through the surface S is the integral

$$\begin{aligned}\Phi &= \iint_S \mathrm{d}\Phi \\ &= \iint_S \vec{B}\cdot \mathrm{d}\vec{S}\end{aligned} \quad (14)$$

The electric and magnetic fields have potential energy. This one thereforepropagates since the fields propagate. This energymakes it possible to create a movement of particles. The notion of electrostaticpotentialisbased on the interaction betweentwo electric charges q and q'. Suppose the first fixed load and the other movingbetweentwo points A and B. The work does not depend on the path taken by the particlebetweenA and B because the electric force is a conservative force. We can therefore define an electricalpotentialenergy by

$$\varepsilon_p = \frac{qq'}{4\pi\varepsilon_0 r} \quad (15)$$

By involving the electric field, we can say that the charge q' moves in an electric field$\vec{E}$created by $q$which produces a force $\vec{f} = q'\vec{E}$. This conservativeforce is related to the potential energy via the relation $\vec{f} = -grad\varepsilon_p$hence

$$\vec{f} = -grad\frac{q}{4\pi\varepsilon_0 r} \quad (16)$$

Finally, while traveling in space, the particle drawspotential energy from the electric field. A similar reasoning applies for an induced magnetic field.The potential energy of a magnet of magnetic moment $\vec{m}$, in a magnetic field $\vec{B}$, is defined as the mechanical work of the magnetic force (in fact, magnetic torque) on the realignment of the vector of themagnetic moment dipole, and is equal to :

$$E_{p,m} = -\vec{m}\cdot\vec{B} \quad (17)$$

Conclusion 8 The mass diffusion transport equation has been represented and explained. However, the energetic formulation of a thermal or magnetic transfer differs. Indeed, from a mathematical point of view, the mass and thermal representationsare done thanks to scalars or functions: the concentration C andthe temperature T. On the other hand, a magnetic field is a vector notion $\vec{B}$. In this case, the calculation of the flow is an integral. The transport equations are influenced by this observation. Note that, in the latter case, the mathematical representation models three phenomena differently: the displacement of the electromagnetic fields, the propagation of the waves and the displacement of the particles located in the region of propagation of the waves. More generally, any conservative force $\vec{F}$derives from a potential energy E_p:

$$\begin{aligned}\vec{F} &= -\vec{\nabla}E_p \\ &= -\overrightarrow{grad}\,E_p\end{aligned} \quad (18)$$

APPLICATION ON EARTH AND SPACE

As explained in the book [7], there are propertiesconcerning the transporter element, whether it isa fluid or a solid, and others concerning the particles or the energy to be transported. By taking intoconsideration all the physical and chemical data ofthe load-bearing element and of the transported element, a mathematical modeling in the form of equations becomes feasible.

On earth

We will present migratory examples of solid particles in a gaseous fluid, then a liquid fluid and finally an energy flow. In the first case, it is a question of transporting dust by atmospheric air. The second example illustrates the migration of minerals in the coastal groundwater. For the energy example, we will present solar radiation. Indeed, it has both corpuscular and wave-like properties. In addition, these radiation exist both in the Earth's atmosphere and in space.The document [16], presents a study of a transfer of a soluble particle in an aquifer.

The particles in the air

Example of dust in the air. When the particles accumulate in the air, clouds form and there is rain.

Particles in a liquid

In the book [3], the example of the study of the variation of the salinity of the coastal groundwater layer is explained. It is modeled by the diffusion-convection equation.

The particles in a stream of solar radiation

In the Earth's atmosphere, the sun's rays have two properties: corpuscular and wave-like. On the one hand, they possess the property of matter because of photons. On the other hand, they have the characteristics of electromagnetic waves. Their displacement is influenced by these two properties. Among these mechanisms: diffusion and radiation. Solar rays transmit thermal and magnetic energy. They have a lot of beneficial effects on life on earth: photosynthesis for plants and the generation of vitamin D by the human body. A magnetic application of solar rays is the generation of electricity in contact with photovoltaic plates.

In space

We tend to say that convection does not exist in space. But let's take a closer look. Space is filled with energies: magnetic energy, thermal energy (coming from the stars), gravity attraction energy (between stars and planet for example) and what it generates as kinematic energy (the planets revolve around the sun). Therefore, we tend to talk about energy in space than about matter, whether it is solid or gaz or plasma. On a smaller scale, specialists have discovered the existence of space dust. It seems to be mobile, but in fact interactions between these particles exist, see article [9]. The questions: do these dusty components undergo the same means of migration as on earth? Do the particles of the gases existing in space migrate according to the same physical laws as on Earth? Diffusion, convection and dispersion?

The interstellar dust

Interstellar dust is mainly formed by stars that have entered the red giant phase of their evolution. The vast majority of interstellar particles come from the residues of stars ejected by the latter at the end of their life. It is made of compounds of various elements such as oxygen, carbon, iron, silicon and magnesium. It originates from the death of stars where stars during their lifetime create metals and explode at their end or blow off their outer layers. The bulk of this dust is formed by grains of size less than $0.1\ \mu m$, but refractory crystals of size approaching or exceeding a micron are also found there. They react to each other randomly

The particles in an interstellar gas

In this paragraph, we present the example of hydrogen gas in space. Hydrogen is the chemical element with atomic number 1, symbol H.

The hydrogen present on Earth has two isotopes. The first consists almost entirely of the isotope ^1H, called protium and comprising one proton and zero neutrons. The second constitutes about 0.01% of deuterium ^2H, comprising a proton and a neutron. These two hydrogen isotopes are stable.

Astrophysical or cosmic plasma

An astrophysical plasma is an ionized gas whose physical properties are studied as a branch of astro-physics. It is believed that a large part of baryonic matter consists of plasma, a state of matter where molecules do not exist; the atoms are so hot that they become ionized by splitting into ions (of positive charge) and electrons (of negative charge). Since the number of charges carried by the electrons and that of those carried by the ions in the plasmas are equal, the latter are generally electrically neutral and therefore the electric fields play a lesser dynamic role. Because plasmas are very conductive, any charge imbalance is quickly neutralized.

The particles in a stream of cosmic solar radiation

In space, the sun's rays have two properties: corpuscular and wave-like. But in space, their displacement is in fluenced by one propertie : magnetic wave. So the transport mechanism is only radiation. At any point in space, these electro magnetic waves generate fields. The electric and magnetic fields have a potential energy: the energy therefore propagates since the fields propagate. The Universe is completely constantly traversed by magnetic fields of various origins. Naturally, at a great distance from the sources, itis extremely weak. The magnetic flux, solar or other origin, drives the particles into space. Solar rays transmit thermal and magnetic energy. The heat flux, solar or other origin, drives the particles, sometimes scientists talk about solar gusts or winds. It is the magnetic flux, solar or other origin, who drives the thermal energy into space. Questions are : Can we talk about magnetic advection in space? Or a solar thermal conduction in space? The responses are négatif, because sun's rays are transported in the space because of their wave behavour and not because of a fluid in motion.

CONCLUSION

In this article, the author makes a comparison of the four mechanisms of transport of solid and energetic molecular particles in two different media. The first is the terrestrial environment, the second is the space environment. Examples are presented.

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